

Evaluating the effectiveness of vegetation conservation on a sacred mountain in western China

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Abstract

Sacred natural sites, as probably the oldest form of habitat reserve for religious or cultural causes worldwide, are suggested to have an important role in conserving vegetation; however, there are insufficient data supporting the detailed implications of such sites for vegetation conservation. Thus, we evaluated the effectiveness of vegetation conservation on a Tibetan sacred mountain in Yajiang County, Sichuan, China, by investigating species richness and the structural attributes of higher vascular plant communities on and around the sacred mountain from April to June 2009. The results showed that the number of tree species on the sacred mountain was significantly higher than that in the surrounding area, but there were no notable differences in the numbers of shrub and grass species between the two sites. The sacred mountain harbored a greater number of small, short trees compared with the surrounding area, wherein the low-shrub and grass understory was relatively dense. We conclude that the sacred mountain has a positive impact on indigenous vegetation protection, but disparities in the management of the allowed uses of such sites could reduce their conservation effectiveness.

Keywords

Forest conservation, indigenous communities, richness, sacred natural site, vegetation structure

Introduction

There are numerous ethnic groups across the world, which have existed for centuries, for the most part from ancient times (Dudley et al. 2005). Many such groups define forests or mountains as sacred areas, protecting such regions for religious or cultural reasons, because they believe that everything has a soul, with some areas having resident deities or spirits. Access to sacred natural sites is usually restricted, and logging is forbidden (Colding and Folke 2001). Thus, sacred natural sites are suggested to be beneficial to vegetation conservation (Bhagwat and Rutte 2006).

Some research has indicated a higher plant diversity in sacred sites compared with open-access sites. For example, Gawade et al. (2018) suggested that sacred groves harbored more threatened and rare plant species relative to associated surrounding plots in Dapoli Taluka, India. Aerts et al. (2016) reported more indigenous woody species owned by Ethiopian church forests compared with corresponding natural forests, while Gao et al. (2013) documented higher tree diversity in culturally protected forests than in nearby forests without cultural protection in southeast China. However, Bhagwat et al. (2005) found that the overall species richness of trees did not significantly differ among sacred groves, officially protected areas, and coffee plantations in the Western Ghats of India. In terms of vegetation attributes, Salick et al. (2007) demonstrated that sacred forests in northwest Yunnan, China preserved some characteristics of old-growth forests; Shen et al. (2015) found that Tibetan sacred mountains of cultural importance had higher forest cover than the nearby unmanaged open-access areas. Whereas, Levy-Tacher et al. (2019) found that few differences existed for structural attributes (e.g., basal area and tree height) between Mayan sacred forests and the nearby areas of mature forests. Thus, given that there are insufficient data supporting the detailed implications of sacred sites for vegetation conservation, more research is required to determine the conservation effectiveness of such sites, especially for poorly known areas (Xu et al. 2019).

In this study, we evaluated the effectiveness of vegetation conservation on a Tibetan sacred mountain in western China. By comparing higher vascular plant (i.e., seed plant) communities on and surrounding the sacred mountain, we investigated whether species richness and the structural attributes of communities differed between the sacred mountain and the surrounding area.

Methods

Study site

The study site was located in Pamuling (30°06'N, 101°11'E; Fig. 1), Yajiang County, Garzê Tibetan Autonomous, Sichuan, China, which occurs in the sub-humid climate zone of the Qinghai-Tibet Plateau. The vegetation comprises five main types: fir–larch forests (dominated by *Abies squamata*, and *Larix potaninii*), mixed spruce–larch–birch

forests (dominated by *Picea* sp., *L. potaninii*, and *Betula platyphylla*), oak thickets (dominated exclusively by *Quercus aquifolioides*), pine forests (dominated exclusively by *Pinus densata*), and rhododendron shrubs (*Rhododendron nitidulum*, *Rh. flavoflorum*, *Salix* sp., and *Dasiphora fruticosa*). The sacred mountain covers ~ 20 km², ranging mainly in elevation from 3,300 to 4,200 m, and was established by a Tibetan Buddhist monastery and associated with a mountain deity (see Xu et al. 2019 for more detail). Unless for the purpose of performing Buddhist worship, people were usually restricted from accessing the sacred mountain by the assigned specific guardians in the monastery. Logging was also prohibited.

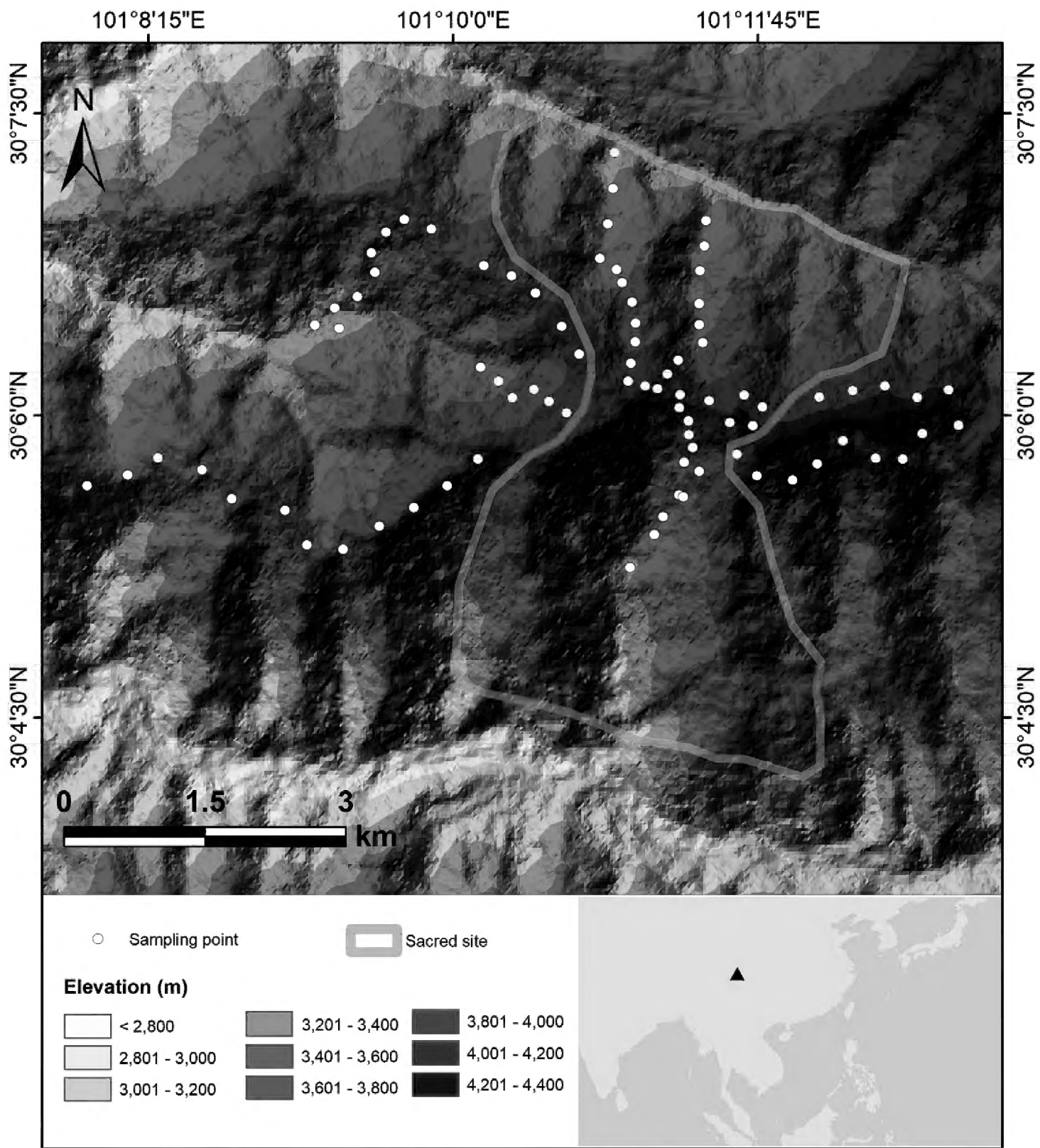


Figure 1. Map showing the location of the study site (black triangle) and sampling points (white dots) on and surrounding the sacred mountain.

The area surrounding the sacred mountain was accessible. The woodlands in the surrounding area were under threat from cutting by the local communities for cooking and heating, despite a national logging ban imposed on natural forests in the upper reaches of the Yangtze River in 1998 (Xu et al. 2016). For comparison with the sacred mountain site, we delimited a range of $\sim 30 \text{ km}^2$ surrounding the mountain, which ranges in elevation from $\sim 3,300 \text{ m}$ to $\sim 4,300 \text{ m}$ and has similar topographical features to the sacred mountain.

Measurement of species richness and community structural attributes

We conducted fieldwork to measure species richness and the structural attributes of higher vascular plant communities (including tree, shrub and grass layers; see Table 1) between April and June 2009. We positioned sample points approximately every 250 m along ten transects of 0.3–5 km established centered on the monastery and its associated mountain deity. We positioned 37 sampling points on the sacred mountain, and 47 sampling points in the surrounding area (Fig. 1). At each sampling point, we established one $10 \times 10 \text{ m}$ plot to record the number of tree species. Based on Di Gregorio (2005) and Ravindranath and Ostwald (2008), we categorized trees into three size groups: (1) small [diameter at breast height (DBH) $< 10 \text{ cm}$], (2) medium ($10 \text{ cm} \leq \text{DBH} < 30 \text{ cm}$), and (3) large trees ($\text{DBH} \geq 30 \text{ cm}$), and into two height groups: (1) short ($< 5 \text{ m}$), and tall ($\geq 5 \text{ m}$) trees. We recorded the number of trees of different size groups and following the method introduced by Prodon and Lebreton (1981), we visually estimated coverage of trees of different height groups. We divided the $10 \times 10 \text{ m}$ plot into four $5 \times 5 \text{ m}$ plots. We recorded the cumulative number of shrub species in the four $5 \times 5 \text{ m}$ plots. We visually estimated coverage of shrubs with height $< 1.5 \text{ m}$ and $\geq 1.5 \text{ m}$ in each $5 \times 5 \text{ m}$ plot, respectively, and averaged the coverage values in the plots. We further nested five $1 \times 1 \text{ m}$ sub-plots (four set in the center of each of the four $5 \times 5 \text{ m}$ plots, respectively and one the center of the $10 \times 10 \text{ m}$ plot), by a five-point sampling method (Zhang 1995). We recorded the cumulative number grass species in the five $1 \times 1 \text{ m}$ sub-plots. We visually estimated grass coverage in each $1 \times 1 \text{ m}$ sub-plot, and averaged the coverage values in the sub-plots.

Statistical analysis

We used multivariate analysis of variance (MANOVA) to examine the differences in richness of tree, shrub and grass species between the sacred mountain and its surrounding area. We used principal component analysis (PCA) on structural attributes measured between the two sites to identify the most prominent gradients, and examined their differences using permutational multivariate analysis of variance (PERMANOVA). We operated the analyses on R 4.0.5 (The R Core Team 2021) with the vegan package (Oksanen et al. 2020) and visualized data with the ggplot2 package (Wickham et al. 2021). $P < 0.05$ indicated statistical significance.

Table 1. Species richness and structural attributes of higher vascular plant communities measured in the study.

Item	Description
Species richness	
Number of tree species	Counted
Number of shrub species	Counted
Number of grass species	Counted
Structural attributes	
Number of trees with DBH < 10 cm	Counted
Number of trees with DBH 10–30 cm	Counted
Number of trees with DBH ≥ 30 cm	Counted
Coverage of trees with height < 5 m	%, Estimated following the method proposed by Prodon and Lebreton (1981)
Coverage of trees with height ≥ 5 m	
Coverage of shrubs with height < 1.5 m	
Coverage of shrubs with height ≥ 1.5 m	
Grass coverage	

Results

The number of tree species in the sacred site was significantly higher than in its surrounding area (Fig. 2A). However, there were no notable differences in the numbers of shrub (Fig. 2B) and grass species (Fig. 2C) between the two sites.

The PCA analysis (Fig. 3) yielded two principal components of community structural attributes (rendered in the form of two axes). The first axis (eigenvalue = 2.64, explaining 33.0% of the variance) represented mainly the structure of the grass and low-shrub understory and canopy, contributed positively by the coverage of grasses and shrubs < 1.5 m in height, but contributed negatively by the coverage of trees ≥ 5 m in height and the number of trees with DBH 10–30 cm. The second axis (eigenvalue = 2.02, explaining 25.3% of the variance) represented primarily the structure of the subcanopy

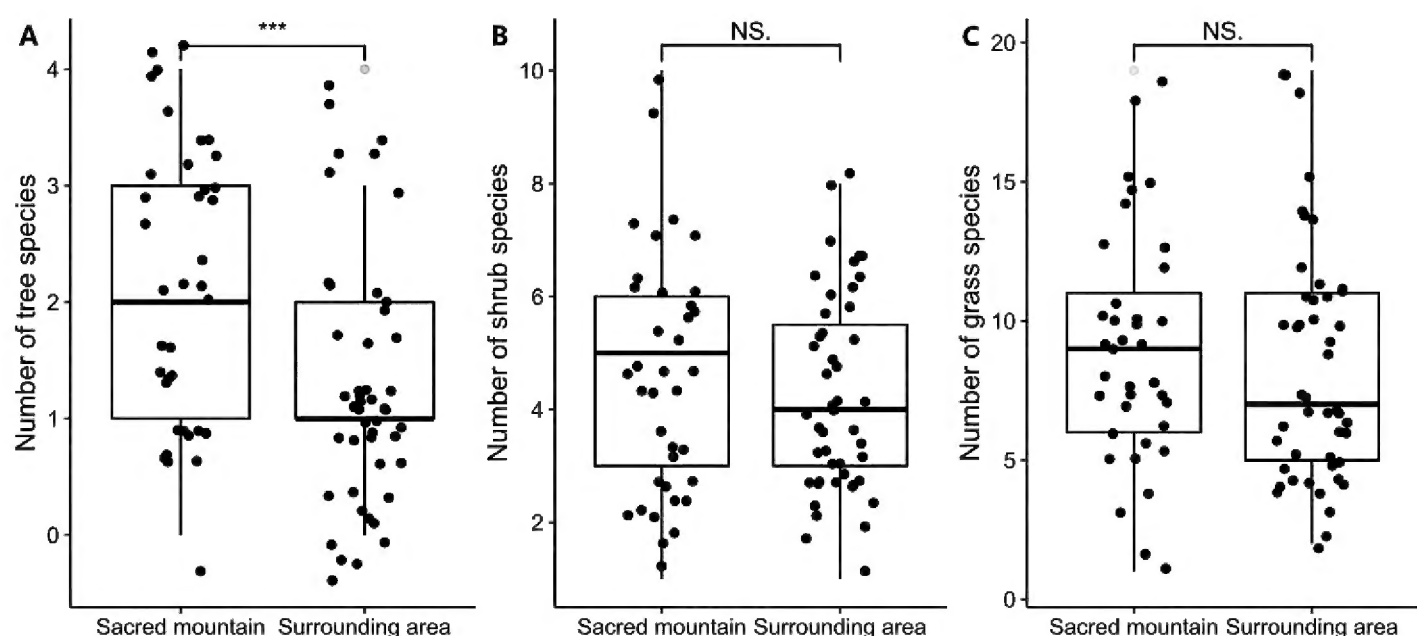


Figure 2. Number of higher vascular plant species between the sacred mountain and the surrounding area **A** tree, **B** shrub and **C** grass. Boxplots show the median, 25th, and 75th percentiles, Tukey whiskers (median ± 1.5 × interquartile range). ***, $P < 0.001$; NS., $P > 0.05$.

and high-shrub understory, contributed positively by the number of trees with DBH ≥ 30 cm, negatively by the number of trees with a DBH < 10 cm, and the coverage of trees < 5 m in height and by shrubs ≥ 1.5 m in height. Although there was a large overlap between the two ellipses where most of the sample sites on both the sacred and its surrounding area were located, PERMANOVA testing indicated a prominent difference in the structural attributes between the two sites, which can be represented by the two significantly separated sections in the lower left corner of the ellipse of the sacred site and the right side of the ellipse of the surrounding area (Fig. 3). The separation indicated that the sacred mountain harbored a greater number of small, short trees compared with its surrounding area, where the low-shrub and grass understory was denser.

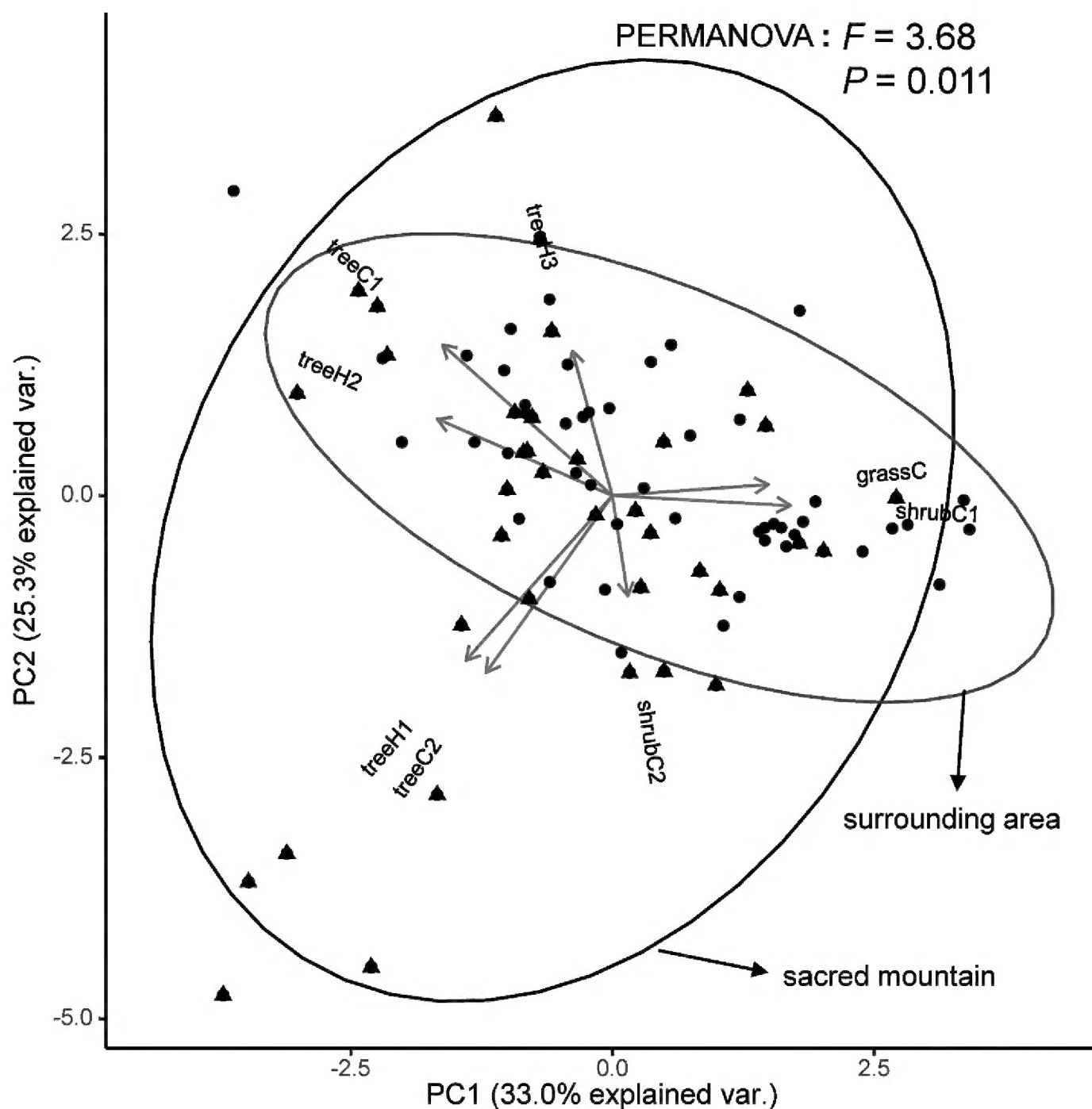


Figure 3. Multivariate principal component analysis (PCA) of the structural attributes of higher vascular plant communities. The triangle and round points, with 95% density ellipses, represent the sacred mountain and its surrounding area, respectively. Abbreviations: treeH1, number of trees with DBH < 10 cm; treeH2, number of trees with DBH 10–30 cm; treeH3, number of trees with DBH ≥ 30 cm; treeC1, coverage of trees with height ≥ 5 m; treeC2, coverage of trees with height < 5 m; shrubC1, coverage of shrubs with height < 1.5 m; shrubC2, coverage of shrubs with height ≥ 1.5 m; grassC, grass coverage.

Discussion

This study investigated the differences in species richness and the structural attributes of higher vascular plant communities between a Tibetan sacred mountain and its surrounding area. The results showed that the sacred mountain maintained a higher number of tree species than the surrounding area, which is consistent with many previous studies on sacred natural sites (Salick et al. 2007; Gao et al. 2013; Aerts et al. 2016; Levy-Tacher et al. 2019). There was a prominent difference in structural attributes between the two sites. The sacred mountain harbored a greater number of small, short trees compared with the surrounding area, whereas low-shrub and grass understory in the surrounding area was relatively dense. In the range of our study site, local people generally harvested trees that were both short and small in diameter, such as *Q. aquifolioides* for fuel, despite a national logging ban imposed on natural forests (Xu et al. 2016). For specific religious and cultural beliefs, local people were not allowed to enter the sacred mountain to cut trees. As a result, trees were more species rich, and the layers of small trees were denser on the sacred mountain than in its surrounding area.

However, we did not find a significantly higher richness of shrub and grass species on the sacred mountain compared with its surrounding area. Previous studies (e.g., Salick et al. 2007; Gao et al. 2013) documented similar results and suggested that they might be the result of the forms of anthropogenic use allowed in a sacred site. In the study site, trees, rather than shrubs or grasses, were commonly considered sacred by the local community, as reported in other sacred sites (Bhagwat and Rutte 2006). Although the use of forest resources, especially of trees, was restricted on the sacred mountain, collection of medicinal and other non-timber plants and grazing were allowed to some extent. This might explain why there was no significant difference in the richness of shrub and grass species between the sacred mountain and the surrounding area.

Nevertheless, the coverage of shrubs < 1.5 m in height and grasses was obviously less on the sacred mountain than in the surrounding area. This might be the result of allelopathy (Zhang et al. 2021) and the shadow effect (Jennings et al. 1999; Guo et al. 2003). The dense tree layer on the sacred mountain might severely restrict the germination of seeds, growth of seedlings, and regeneration of low shrubs and grasses. By contrast, the renewal of low-shrub and grass layers was promoted in the surrounding area where the coverage and number of small trees was both relatively low.

In conclusion, this study revealed the effectiveness of vegetation conservation on a Tibetan sacred mountain in western China. In terms of access and utilization, such sites can complement officially protected areas. However, 'sacred' might be a relative term, given disparities in the management of allowed uses of resources such as trees, shrubs, and grasses. Therefore, conservation knowledge based on community ecology should be introduced to indigenous communities. In addition, the sacredness of a site might mean more to local peoples than to outsiders (Shen et al. 2015). Tourism based on the Tibetan traditional culture and customs has flourished in recent years, along with the rapid development of road construction in western China (Brandt et al. 2012). Tourists often tend to disturb these sites and the relative lack of restrictions could threaten cultural assets and even modes of life. Hence, we suggest additional leg-

islative protection with strict restrictions for the activities of local people and tourists, to help protect these important conservation areas.

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